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GEOLOGY OF THE DANA POINT QUADRANGLE, ORANGE COUNTY, CALIFORNIA

1974

CALIFORNIA DIVISION OF MINES AND GEOLOGY

PREPARED IN COOPERATION WITH THE
COUNTY OF ORANGE, DEPARTMENT OF BUILDING AND SAFETY,
ROAD DEPARTMENT, AND THE ORANGE COUNTY FLOOD CONTROL DISTRICT.

SPECIAL REPORT 109

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Special Report 109

GEOLOGY OF THE DANA POINT QUADRANGLE, ORANGE COUNTY, CALIFORNIA

This report is based on work completed in 1970.

By

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Orange County Flood Control District

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INTRODUCTION

The geology of the Dana Point quadrangle, located in southern Orange County and midway between Los Angeles and San Diego, was studied during 1968 and 1969 with particular regard to surficial geological features. The investigation was done in cooperation with the County of Orange Road Department, Department of Building and Safety and the Orange County Flood Control District. Its purpose was to produce a geologic map having sufficient detail for use as a basic reference for determining potential hazards to urban development. The map should not, however, be used as a substitute for detailed geologic site investigation.

Mapping was done with the aid of 1967 airphotos on the 7-1/2 minute U.S. Geological Survey topographic quadrangle enlarged to 1:12,000 scale. Previous mapping of the quadrangle by Vedder, Yerkes and Schoellhamer (1957) of the U.S. Geological Survey was heavily relied upon for bedrock geology and stratigraphic nomenclature. Nonetheless, modifications were made in areas of new exposures and in areas where more detailed field examinations led to new interpretations. Consulting firms, including Moore & Taber, J.E. Slosson & Associates, Geo-Technical Consultants and Geo-Labs, provided detailed geologic and soils information on some localities. Cooperation of the landowners, consultants and county officials is gratefully acknowledged.

The land area of the quadrangle is divided into two upland regions separated by the southwest-trending, alluviated valley of San Juan Creek. Both upland areas consist of rounded, grass and brush-covered hills of moderate relief with broad, gently sloping surfaces extending well inland from the southwest. A prominent, north-trending ridge extends about one mile into the quadrangle near its northwest margin. Maximum relief within the area is 888 feet.

Exposures of bedrock are poor and scattered except along the steeper parts of the sea cliffs, in some steepsided gullies, and along fresh or unvegetated cut slopes graded during urban development. No subsurface explorations were made, although drill logs of some exploratory wells for petroleum were examined.

Rainfall averages between 12 to 15 inches annually, nearly all occurring during the late fall, winter and early spring. The climate is Mediterranean to semi-arid with the coastal oceanic influence diminishing rapidly inland toward the Santa Ana Mountains.

GEOLOGIC SETTING

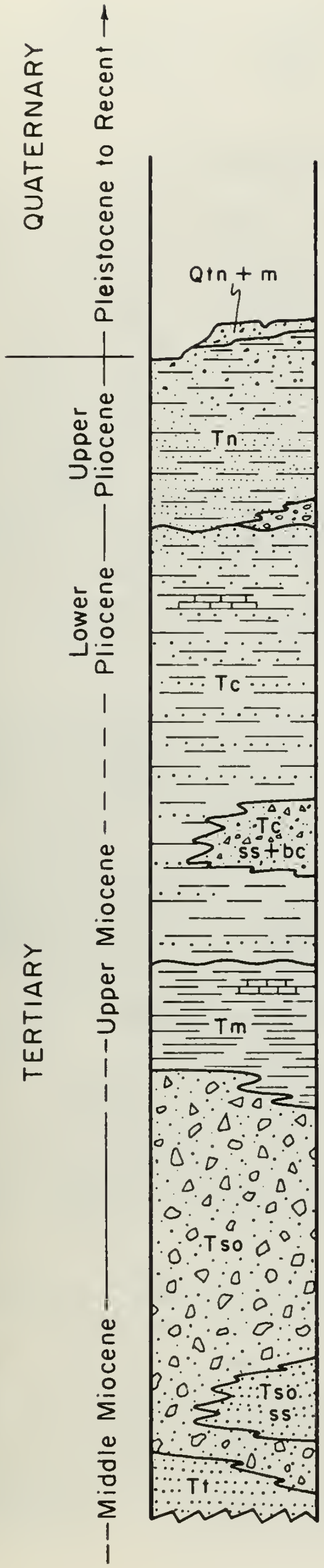
The Dana Point quadrangle comprises a part of the western flank of the Peninsular Ranges of southern California and includes areas of the western foothills of the Santa Ana Mountains and the southeastern flank of the San Joaquin Hills. Part of the southern end of the Capistrano syncline occupies the central sector of the quadrangle. The complexly faulted anticlinal structure of the southern part of the San Joaquin Hills extends into the northwestern part of the quadrangle.

With the exception of Quaternary terrace and alluvial deposits, all exposures are of marine sedimentary rocks of Miocene and Pliocene age. The oldest rocks, the middle Miocene Topanga Formation and San Onofre Breccia, are exposed near the western margin of the quadrangle. These rocks are the most stable and resistant to erosion and form topographic highs in this area. The only outcrop of the Topanga Formation within the quadrangle is a lenticular body of cemented sandstone and conglomeratic sandstone exposed at Niguel Hill. In the slightly younger San Onofre Breccia, probably locally interbedded with the Topanga Formation, coarse angular detritus of Catalina Schist is commonly dominant.

A fairly continuous section of marine sedimentary rocks, from middle Miocene through lower Pliocene, is exposed to the east of the San Onofre Breccia within the quadrangle (see Plate 1). These sediments include deep water diatomaceous and foraminiferal shales, siltstone and chert of the Monterey Formation and diatomaceous and silty shales, siltstone, mudstone and fine-grained sandstone of the Capistrano Formation. These sediments were deposited in the Capistrano embayment (Fernandez, 1959 and Ingel, 1962) during the development of the Capistrano syncline. Subsequently, regional uplift and erosion occurred followed by subsidence during which time the late Pliocene Niguel Formation (Vedder and others, 1957) was unconformably deposited upon the Capistrano Formation. The Niguel Formation is primarily made up of fine-grained sandstone and sandy siltstone and locally contains a basal conglomerate.

Gradual emergence of the region from the sea occurred in Pleistocene time and numerous wave-cut platforms, most of which were covered by thin marine terrace deposits, were formed as the sea receded from the land. The erosion of adjacent highlands provided a nonmarine sedimentary cover on most marine terrace deposits. Pronounced elevation and erosion of the Santa Ana Mountains produced gravel and finer sediments that are locally preserved as stream terrace deposits, especially along the northern banks of San Juan Creek. Accelerated erosion during periods of heavy rainfall, coupled with the lowering of the base sea level during Quaternary times, resulted in the oversteepening of many slopes along major drainage courses. As a result, major landslides occurred, especially in the weak sedimentary rocks of the Capistrano Formation. Many of these landslides are at present difficult to identify due to long periods of erosion that subdued their geomorphic features. Some slides have been partially buttressed by alluvium. Erosion and alluvial deposition is still taking place along with landsliding caused by a variety of geologic factors.

STRATIGRAPHIC COLUMN



Marine and Continental Terrace Deposits --- conglomerate, gravel, sand and silt commonly interbedded.

Niguel Formation --- fine sandstone and sandy siltstone, locally with basal conglomerate.

Capistrano Formation --- siltstone, mudstone and soft diatomaceous and silty shale with minor sandstone beds and lenses, locally with channels filled by coarse sandstone, breccia and conglomerate, and minor calcareous shale beds and lenses.

Monterey Formation --- interbedded diatomaceous, silty and siliceous shale and siltstone with minor chert, limestone and calcareous shale beds and lenses.

San Onofre Breccia --- sedimentary breccia and conglomerate with coarse sand, angular to rounded boulders, cobbles and pebbles of schist, quartzite and gabbro in sandy and earthy matrices, locally interbedded with sandstone and sandy siltstone.

Topanga Formation --- sandstone and conglomeratic sandstone.

The region is underlain by essentially the same sedimentary sequence of older Tertiary and Cretaceous rocks that are exposed eastward on the western flank of the Santa Ana Mountains, but surficial exposures of these older rocks are lacking in the study area.

LANDSLIDES AND SLOPE STABILITY

Landslides are both numerous and widespread within the Dana Point quadrangle and range in size from a few square feet to more than 450 acres. Landslides appear to occur in greater abundance on northerly and easterly facing slopes, where evaporation rates are lower than on southerly and westerly facing slopes. Inherently weak rock types, such as those found in the Capistrano and Monterey Formations, and other rocks containing adversely dipping planar features such as faults, joints and bedding planes, are also factors directly related to landslide causation in this area. Most landslides within the quadrangle are rotational slumps modified in varying degrees by local structural features. Rockfalls and rockslides from the sea cliff are also common along much of the seacoast. Slopes underlain by the Topanga Formation and the San Onofre Breccia, comprised mainly of sandstone and conglomerate, are much more stable than those underlain by the fine-grained rocks of the Monterey and Capistrano Formations.

The larger landslides are situated in two areas in the northeastern part of the quadrangle: 1) along the southeast side of the San Juan Creek and 2) adjacent to Prima Deshecha Cañada. Steep slopes in these two areas were probably formed during the late Wisconsin glaciation low stand of sea level when incisement of river valleys was relatively rapid. One landslide along a southern tributary of San Juan Creek was dated 17,180 (± 750) years before present by carbon 14 dating techniques on wood found in soil buried by the landslide (Stout, 1969). Although many slope failures are ancient and partly buttressed by alluvial deposits, they may still be susceptible to renewed sliding.

Several major landslides have occurred along the sea cliff northwest of Dana Point. These are modified rotational slumps in sharply folded beds of the Monterey and Capistrano Formations. Wave erosion of the lower portions of these landslides or the addition of water to these already unstable deposits could initiate renewed movement of these old slide masses.

Rockslides and debris slides are especially prominent along the inland side of State Highway 1, from the mouth of San Juan Creek southeastward into the City of San Clemente. Although protected from wave erosion by the beach and highway, the sea cliff is failing at an accelerated rate due to increased seepage from heavy periodic rainfall and irrigation of yards in the urbanizing areas inland. Similar failures will take place wherever steep slopes composed of inherently weak sedimentary rocks are subjected to a large increase in water content.

Several small block-glide landslides - the unit movement of rock materials along a planar surface - have occurred during and since the 1969 rainstorms in the cut slope along the ramp from Highway 1 to the San Diego Freeway. The landslides are in "daylighted" north-dipping shale beds of the lower Capistrano Formation. Landslides, including shallow earthflows, are common elsewhere in the Capistrano Formation. These landslide deposits appear to range in areal extent from a few square feet to many acres, and in thickness from a few inches to 40 or more feet. Most are located along steepsided tributary canyons or along prominent bedrock ridges.

Sandstone of the Topanga Formation, lacking the typical siltstone interbeds, is exposed in the northwestern part of the quadrangle. The sandstone dips moderately and uniformly toward the west and is partly bounded by steeply dipping faults. The sandstone does not appear to be extensively sheared even when in proximity to faults. The formation is stable in natural slopes. These beds, if exposed by grading, however, could undergo differential erosion, possibly leading to massive, bedding plane slope failures.

The San Onofre Breccia appears to be a relatively stable unit. A few large rock falls and block-glides have occurred along the sea cliffs and from steep faces formed by differential erosion along steeply-dipping faults. On inland slopes, large blocks of breccia and boulders have weathered out of the matrix and balance precariously on steep slopes. These are distinct hazards to the activities of man downslope.

Debris flows and earthflows have occurred during and after heavy rainfall in areas of loose boulders and deep soils, especially in those areas of soils derived from the earthy-matrix facies of the San Onofre Breccia (see Description of Bedrock Units). Infiltration of rainwater is increased by shrinkage cracks in the expansive soils of the earthy-matrix. The moisture accelerates weathering, reduces soil strength and adds weight to the rock and soil. Water also lubricates planes of potential failure at the soil-bedrock contact and along fault surfaces within the rock.

Uniform cut slopes are difficult to attain in the San Onofre Breccia due to great differences in local cementation and in included rock sizes. Moderately steep natural slopes - even those unprotected by vegetation - are commonly more stable than the gentle slopes because they are generally composed of more resistant facies of bedrock.

GRADING AND SOILS

Most of the bedrock and surficial geologic units can easily be excavated and remolded as fill with modern grading equipment. Heavy ripping and some blasting may, however, be required in the well-indurated and well-cemented facies of the San Onofre Breccia and the Topanga and Capistrano Formations.

Soils derived from the Monterey Formation, much of the Capistrano Formation, and the San Onofre Breccia are moderately to highly expansive. Much of the bedrock of these formations, when disaggregated by grading equipment for use as fill, is also slightly to moderately expansive. To reduce cracking and other adverse effects of expansion on foundations, special engineering designs are commonly required in construction, including the use of reinforcing steel in foundations, drainage control devices, over-excavation and backfilling with non-expansive soils, etc.

FLOODING

The major drainage courses in the Dana Point quadrangle are: Segunda Deshecha Cañada (mouth only), Prima Deshecha Cañada, Deep Canyon and Reservoir Canyon (tributaries joining San Juan Creek from the southeast near its mouth), San Juan Creek (including the mouth of tributary Trabuco Creek), and Salt Creek (including tributary Arroyo Salada and two unnamed tributaries from the east). All are subject to flooding during heavy rainstorms or abnormally wet rainy seasons. The rainy season normally occurs in the late fall, winter and early spring.

With the exception of the San Juan and Trabuco Creek systems, drainage systems are relatively small within the area. Even if the drainage basins are small, however, the smaller drainage courses are now developing year-round flows due to the increased irrigation within urban developments. The decreasing use of ground water and the increasing use of imported water for irrigation are causing ground water levels to rise. Ultimately, this will reduce the amount of rainfall required to produce flooding in drainage courses. Each of the smaller drainage systems, if their courses are blocked or altered by grading, will require adequate subsurface drains; design requirements should be based on watershed size and considerations of man-induced runoff. The low permeabilities of most of the local soils and bedrock formations tend to induce heavy runoff from prolonged heavy rainfall during an unusually wet winter.

The San Juan and Trabuco Creek systems drain a large basin of about 166 square miles (Newton, 1960, p. 20). In the Dana Point quadrangle, San Juan Creek occupies a limited part of a broad alluvial plain that ranges in elevation from sea level to slightly above 100 feet. All but the upper one-half mile of San Juan Creek and all of Trabuco Creek within the quadrangle have been channelled between concrete-lined flood control embankments. Existing flood control facilities, however, are inadequate to prevent widespread damage during unusually wet years. During the 1969 storms, about 1,500 feet of the northwest embankment along San Juan Creek was washed out. Flooding and erosion of part of the alluvial plain resulted in damage to sewage lines and other underground utilities.

Large waves generated by storms at sea, or by seismic sea waves (tsunamis) resulting from off-shore earthquake activity, could flood large areas of low elevation along the seacoast. Waves from six to ten feet in height are fairly common and may arrive at the coastline during almost any season of the year (Newton, 1960). Higher waves have been reported, but accurate data relating to size and frequency are not available for this part of the coastline. Storm-generated waves have periodically caused damage to structures built on beach deposits south of the mouth of San Juan Creek and have severely eroded the beach (see Description of Surficial Units). By June 1972, storm waves generated at sea had washed over the breakwater at Dana Harbor at least twice since its completion in 1968.

FAULTING AND SEISMICITY

Evidence of active faulting is not apparent within the Dana Point quadrangle, and all faults mapped during the course of this investigation appear to be pre-Holocene in age. Nonetheless, in 1812, the Mission in San Juan Capistrano was nearly destroyed and people were killed as a result of earthquake shaking. This earthquake episode was, it is believed, related to movement along either the Newport-Inglewood fault zone, about three miles offshore from Dana Point, or the Elsinore fault zone that lies outside of the Dana Point quadrangle. Although no major damage was reported within the quadrangle during the 1933 Long Beach Earthquake (magnitude 6.4) or the 1971 San Fernando Earthquake (magnitude 6.4), several active fault systems in southern California appear to be sufficiently close to produce damaging earth shaking. The recurrence interval for earthquakes with epicenters close enough to cause significant damage to structures within the quadrangle is unknown, but the event of 1812 would certainly indicate that a seismic risk situation exists within the area.

Epicenters of five minor earthquakes have been located within the Dana Point quadrangle during the period 1934 through 1971 (California Institute of Technology, written communication, 1972). A 3.5 magnitude quake occurred immediately south of San Juan Capistrano on March 3, 1952. A 3.1 magnitude earthquake was recorded on February 13, 1967 about one mile offshore and south of Capistrano Beach. On July 26, 1970 about 1 1/2 miles offshore and west of Dana Point, another 3.1 magnitude earthquake was noted. On July 31, 1937 an earthquake of magnitude 2 was recorded at sea in the extreme northwest corner of the quadrangle and about half a mile west of South Laguna. Another magnitude 2 earthquake was located about four miles southwest of Dana Point on September 9, 1936.

Numerous small earthquakes having magnitudes as great as 5.5 have been recorded outside of, but within a 20-mile radius of, the Dana Point quadrangle between 1934 and 1972. These were probably related to adjustments along faults lying within this region. During this time, none of these movements had produced an earthquake with magnitudes greater than the Long Beach Earthquake of 1933 and no surface rupturing has been reported.

Finally, in considering future building within the area, it should be noted that earthquakes tend to cause greater damage to buildings and structures founded on poorly consolidated materials, such as landslide deposits, stream alluvium, and slopewash. Weak sedimentary rocks, such as the deeply weathered or fractured siltstone and shale of the Monterey and Capistrano Formations,also constitute relatively poor foundation materials. Ground surface failure due to differential settlement of poorly-consolidated sediments or artificial fill, and landslide debris could occur during severe shaking. Liquefaction-type ground failure could also occur in saturated, poorly consolidated sediments and in poorly consolidated sediments in which ground water levels are close to ground surface. No such ground surface failures, however, have been documented within the Dana Point quadrangle during historic earthquakes.

DESCRIPTION OF BEDROCK UNITS*

NIGUEL FORMATION; Map designation; Tn; marine.
Material:

Sandstone: fine grained, white to light gray and dusky yellow, friable to weakly cemented, poorly bedded, moderately well sorted, micaceous, moderately permeable, interbedded with

Sandy siltstone: fine grained, medium gray, poorly bedded to massive, slightly to moderately permeable, and

Conglomerate: pebble to cobble, mostly moderate brown to moderate yellowish brown, uncemented to weakly cemented, poorly consolidated, mostly sandy matrix but locally expansive clay matrix, moderately to highly permeable.

The Niguel Formation, named by Vedder, et al., 1957, from the Niguel land grant in the San Juan Capistrano quadrangle, has its type area immediately west of the old Galivan overpass on old U.S. Highway 101 (now the vicinity of the Oso Parkway interchange on the San Diego Freeway-Interstate 405) about 4 1/2 miles north of San Juan Capistrano. As defined by Vedder, et al. (1957), the Niguel Formation includes rocks previously mapped by Woodford (1925), as parts of the San Mateo Formation and Capistrano Formation.

The Niguel Formation is reported to contain a molluscan fauna of Pliocene age (Vedder, et al., 1957, and Vedder, 1960) and to have a regional maximum thickness of about 350 feet.

The Niguel Formation, within the Dana Point quadrangle, is limited to the capping of a few ridges and rounded peaks. These remnants range in thickness from 20 to 150 feet, and they unconformably overlie the Capistrano Formation. The conglomerate facies is generally at, or near the base of the Niguel Formation. It contains clasts of volcanic and metavolcanic rocks, granodiorite, quartz diorite and quartzite with minor amounts of calcareous and phosphatic nodules. The conglomerate is locally absent. A well-cemented, fossiliferous basal sandstone is rare within the Dana Point quadrangle. The Niguel Formation is locally gypsiferous and crystals of fine-grained gypsum commonly line joints and fractures, especially in the siltstone facies. Minor beds, lenses and nodules of light-gray calcareous shale and pale-brown phosphatic shale may also be present in places within the formation.

Bedrock of the Niguel Formation is generally flat-lying and undeformed. Bedding dips gently toward the south and southwest. Niguel Formation terrain is typically moderately rounded, but with slightly steeper slopes than those of the underlying Capistrano Formation. Outcrops are rare, occurring mostly in steepsided gullies. The vegetation commonly associated with the Niguel Formation is mainly a sparse to moderate grass cover with some brush and cacti, mostly prickly pear and cholla.

*(see Appendix B for physical properties including rippability, soil classification, expansivity and consolidation potential)

The Niguel Formation bedrock is generally very stable, even though commonly affected by gully and sheet wash erosion, especially on freshly exposed surfaces. The soils developed on the Niguel Formation are generally one to two feet thick and nonexpansive (sandstone and sandy conglomerate) to moderately expansive (siltstone and conglomerate with clayey matrix). These soils range from moderate yellowish brown to grayish brown, fine sandy to clayey silt to silty clay. Moderate reddish brown to moderate brown sandy clay with gravel soils are developed on the basal conglomerate. Slopewash, which is not widespread on the Niguel Formation is similar to the soils, but somewhat coarser, less compact and more porous. Niguel Formation bedrock is mostly fair to good for fill and generally easily ripped and graded.

CAPISTRANO FORMATION; Map designation; Tc; marine.
Material:

Siltstone, mudstone, and silty shale: (Tc and Tc_{sts}) medium to dark gray and brownish gray to dark greenish gray, poorly to moderately consolidated, massive to moderately fissile, micaceous, slightly permeable;

Sandstone: (Tc_{ss}) fine to medium grained, angular to subrounded, moderate yellowish brown to pale yellowish brown and medium gray to light gray, weakly cemented, poorly to moderately well sorted, massive to poorly bedded, moderately to highly permeable;

Diatomaceous siltstone and shale: (Tc_{dsts}) white to medium gray and brownish gray, soft, very porous, low density, fissile (commonly with white partings), moderately permeable;

Sandstone and breccia: (Tc_{ss+bc}) coarse grain; angular to rounded pebbles and cobbles of granodiorite, quartz diorite, volcanic and metavolcanic rocks, quartzite, blue and green schists, siltstone, calcareous shale, and slabs and lenses of calcareous and ferruginous cemented breccia and sandstone; moderate yellowish brown to pale yellowish brown; massive to poorly bedded with lenses of poorly graded gravel and interbeds of well-graded sand and silt; weakly cemented to friable, moderately permeable.

The Capistrano Formation was named for exposures in the San Juan Capistrano area by Woodford (1925), on the basis of lithological differences in the typically light-colored shales of the Monterey Formation. White (1952) confirmed the late Miocene and early Pliocene age of the Capistrano Formation and suggested following notations in stratigraphic sections of Bramlette (1946), a correlation between the Miocene section and the Malaga Mudstone Member of the Monterey Formation (Woodring, et al., 1936, p. 146). He proposed that the Pliocene section, mainly siltstone and fine grained sandstone, be correlated with and named the Repetto Formation as in the Los Angeles Basin. However, this renaming of the Pliocene section of the Capistrano Formation has not found favor, probably because, as White himself noted, "the contact appears to be gradational..." and "... obscured over much of the area by vegetation or soil cover..." (White, 1952, p. 14-15). Vedder, et al. (1957) subsequently noted that some rocks previously mapped as part of the Capistrano Formation were separated from beds of the typical Capistrano lithology by an erosional and slight angular unconformity. As previously noted, these rocks of the overlying unit were named the Niguel Formation.

The Capistrano Formation west of Oso Creek in the San Juan Capistrano quadrangle is unconformable on the Monterey Formation (Smith, 1960, p. 475-476 and 478). Exposures of the contact within the Dana Point quadrangle are poor and do not clearly show this relationship. Neblett (1966, p. 30) states that the contact appears conformable in the Dana Point area. The presence, in the Monterey Formation, of undulating bedding seldom seen in the Capistrano; the presence in places of angular discordances of bedding attitudes in the two formations in the vicinity of Salt Creek; and the sporadic deposition of sandstone and breccia at and near the base of the Capistrano Formation suggests at least local unconformities at the contact.

The Capistrano Formation contains an upper Miocene microfauna of the upper (?) Mohnian stage (Smith, 1960, p. 467 and 479), and of the Delmontian stage (White, 1952, p. 11-13) and a lower Pliocene fauna of the upper Repettian stage (White, 1952, p. 16).

The maximum thickness of the Capistrano Formation in the region is about 2,400 feet (Yerkes, et al., 1965) and the greatest thickness within the Dana Point quadrangle is nearly the same.

Coarse sandstone and breccia (Tcss+bc) are exposed within the Capistrano Formation in the sea cliff and several inland portions of Dana Point. They occur in two major bodies, probably originating as deep-sea fan channels, which were eroded and then filled by sandy and rocky debris flowing in turbidity currents, or as bed load material in channelled bottom currents, during late Miocene time (Bartow, 1964, Bartow, 1966, Normark and Piper, 1969, and Piper and Normark, 1971). The lithology of these deposits is described above as sandstone and breccia ($\mathrm{Tc_{ss+bc}}$). They locally contain flame structures. These rocks dip as steeply as 35 degrees to the north and northeast similar to adjacent and interfingering siltstone beds of the Capistrano Formation. These deposits are similar in physical appearance to rocks exposed at San Clemente Beach Park. Although the San Clemente exposures were mapped as part of Woodford's (1925) San Mateo Formation of Pliocene age (Blanc and Cleveland, 1968, p. 12 and map legend), more recent studies indicate that they are also a part of the Capistrano Formation of late Miocene age (O.E. Weser, in Bergen, 1971, and J.G. Vedder, personal communication).

The Capistrano Formation dips gently to the north and northeast except in the northeastern part of the quadrangle where bedding dips gently toward the west. It contains concretionary lenses and locally continuous beds of pale yellowish brown to dark-gray, hard calcareous shale and limestone, as much as three feet thick. Fractures, bedding planes and joints are commonly stained moderate brown to moderate yellow or filled with crystals of gypsum.

The Capistrano Formation terrain is typically rounded. It generally has slightly steeper slopes than those of the underlying Monterey Formation and slightly less steep than those of the overlying Niguel Formation. It commonly has steep sided, incised, tributary canyons. Vegetation associated with the Capistrano Formation is mostly a light to moderate growth of grass and low brush with some cacti and locally abundant mustard.

The Capistrano Formation is mostly soft, poorly consolidated rock, subject to creep and massive failures even in areas of low relief. Slope failures occur both along and across bedding planes as rotational slumps, block-glides and rockfalls. Bedding plane landslides (block-glides) occur mostly in the area where exposed bedding planes have been in the shaly facies, mainly found in the lower part of the formation. Rockfalls occur primarily from the steep seacliff along Highway 1 between Capistrano Beach and San Clemente. The rock falls are due to failures along exposed steeply dipping joints that strike parallel to the cliff face and define large blocks of shale of the Capistrano Formation.

Steep slopes were formed by rapid incision of intermittent streams in tributary canyons, as the result of the lowering of the local base level during late Pleistocene or early Holocene times. These slopes are generally unstable and may lack protective vegetation because of continual sloughing. Deep gullying within the Capistrano Formation is common, especially on freshly exposed surfaces and in sheared zones. This gullying leads to further instability of the oversteepened slopes.

Gypsum and mica are planar structured minerals having low shear strength across their cleavage. The presence of these minerals in significant quantities in the Capistrano Formation contributes to the general instability of the bedrock and its soils. Underground drainage commonly forms by piping along fractures, joints and bedding. Eventual failure of the overlying siltstone and soil forms collapse structures as deep as 20 feet and as broad as ten feet in diameter (Neblett, 1966, p. 31-32).

Weathering of the Capistrano Formation is generally deep and earthflow slope failures are common on gentle to moderately steep slopes. The earthflows are seldom more than three to five feet thick and typically include weathered rock debris with the upper soils. Earthflows can cause considerable damage to structures when they occur. Although not thick, these earthflows are difficult to stabilize and frequently lead to deeper failures.

The sandier materials of the Capistrano Formation make good artificial fill but the typical siltstone and mudstone are relatively poor fill material due to their expansive nature, poor drainage characteristics, and relatively poor compactability. The diatomaceous siltstone and shale make poor fill because of their low density, high porosity, poor drainage, and poor compactability.

Soils ("A" and "B" horizons) developed on the Capistrano Formation are generally dark gray to grayish brown, moderately expansive, slightly organic, silty to sandy clay, ranging in thickness from a few inches to two or three feet. The weathered zone ("C" horizon) in the siltstone and mudstone commonly extends 20 or more feet below ground surface. Soils developed on the sandstone and sandy siltstone of the Capistrano Formation are generally about one foot thick, moderate yellowish brown to grayish brown, slightly expansive to non-expansive silty to clayey sand, silt and silty clay. Slopewash developed primarily from siltstone and mudstone of the Capistrano Formation may range in thickness from an estimated three feet to more than ten feet. Slopewash materials are generally yellowish brown to grayish brown, moderately expansive, poorly compacted, porous, fine sandy to silty clay or clayey silt of low to moderate permeability. Areas of deep slopewash are common on many of the larger landslide masses.

MONTEREY FORMATION; Map designation; Tm; marine.
Material:

Diatomaceous shale: white to light gray, soft, fissile; interbedded with,

Silty shale and siltstone: pale brown to dusky yellow and light olive gray, soft, porous, gypsiferous;

Siliceous shale: pale olive to light olive gray, dense, hard, thin bedded;

Chert: light gray to black and brownish black, hard, thin bedded; and,

Limestone and calcareous shale: light olive gray and grayish brown to dark gray, dense, hard, in thin beds and lenses.

The soils and bedrock of the Monterey Formation generally have poor drainage and low permeability, but deep penetration of surface waters occurs through extensive shrinkage cracks in the expansive soils and fractures in the bedrock, especially in the areas of sharp folding covered by marine terrace deposits. Seepage from fractures and along folded bedding planes is common along the base of the sea cliff northwest of Dana Point and may occur elsewhere.

The Monterey Formation is a widespread group of predominantly highly siliceous shales deposited during Miocene time in a marine environment. The formation was named for exposures near Monterey, California. The name has subsequently been applied to rocks of similar age and lithology which are exposed from north of San Francisco to south of Los Angeles (Bramlette, 1946, p. 2).

The Monterey Formation in the Dana Point quadrangle conformably overlies and, in places, appears to interfinger with the San Onofre Breccia. Most of the Monterey Formation is considered to be younger than the San Onofre Breccia, but beds and lenses of schists and other metamorphic rock debris typical of the San Onofre Breccia were emplaced within the white shales of the Monterey Formation. The most notable of these debris lenses is exposed in the sea cliff between Salt Creek and Dana Point (Woodford, 1925, p. 212-214). This outcrop has been mapped in this study as San Onofre Breccia mainly because the physical characteristics of the rock more closely resemble those of the San Onofre Breccia than those of the shales of the Monterey Formations.

The Monterey Formation within the Dana Point quadrangle appears to be unconformably overlain by the Capistrano Formation and is generally much more sharply folded and deformed than the Capistrano Formation in most localities. Bedding is commonly undulating to sharply folded and well-fractured.

The Monterey Formation in this region, specifically in the adjacent San Juan Capistrano quadrangle, is considered to be middle to late Miocene on the basis of Luisian and lower Mohnian microfauna (Smith, 1960, p. 463).

The Monterey Formation is reported to be about 575 feet in thickness at the sea cliff between Salt Creek and Dana Point (Woodford, 1925, p. 212-214). The maximum section noted in the Dana Point quadrangle during this study, however, was about 550 feet.

The regional dip of the Monterey Formation along Arroyo Salada, near the northern edge of the Dana Point quadrangle, is about 20 degrees toward the east, reflecting the presence of the west limb of the Capistrano syncline. Between Dana Point and Salt Creek, the Monterey Formation has undergone severe deformation, resulting in about 15 folds with short wave length and relatively high amplitude within a thousand foot length of the sea cliff. The amplitude of folding ranges from about ten to 50 or more feet. To the northeast a wedge shaped fault block occupies the area at the junction of Salt Creek and Arroyo Salada.

The Monterey Formation terrain generally has gentle slopes and well rounded and subdued hills. The Monterey Formation crops out only in the northwestern part of the quadrangle and occurs in relatively narrow bands. Extensive creep and a few large slope failures are evident in this area, particularly in the sea cliff northwest of Dana Point. Vegetation is moderately heavy, but nearly always restricted to weeds and grasses, including abundant mustard.

The Monterey Formation is generally weak and unstable because of its high porosity, low density and poor drainage. It has a fissile structure, with soft clayey beds interposed between thin more competent beds. Water penetrates deeply into its platy structure through cracks in expansive soils and numerous joints and fractures in the rock. Shear strength of the rock is greatly reduced by an increase in moisture.

Both bedrock and soils of the Monterey Formation make generally poor quality fill material due to low density, high porosity, poor drainage characteristics, abundance of expansive clays and poor compactability.

Soils developed on the Monterey Formation are generally dark gray to black, moderately to highly expansive, and contain slightly organic lean clays with a relatively high plasticity and liquid limit, often approaching the fat clay classification. These soils are commonly about three feet thick. Slopewash developed mainly from the Monterey Formation is as much as ten feet thick, but is not widespread within the Dana Point quadrangle. It is generally grayish brown to dark gray, moderately to highly expansive, poorly compacted, porous, silty clay, commonly with relatively high plasticity, and of low to medium permeability.

SAN ONOFRE BRECCIA; Map designation; Tso; marine.
Material:

Sandy conglomerate and sandy breccia: dusky yellow to moderate yellowish brown and medium bluish gray to dark greenish gray and medium gray, fine to very coarse, massive to poorly bedded, poorly to well sorted, poorly to well cemented, slightly to moderately permeable;

Earthy conglomerate and earthy breccia: moderate brown to dark reddish brown, fine to very coarse, massive to thick bedded, poorly sorted, poorly cemented, clayey, slightly permeable; and,

Sandstone and conglomeratic sandstone: dusky yellow to moderate yellowish brown and medium gray to greenish gray, fine to coarse grain, angular to subrounded grains, angular to rounded pebbles, thick bedded to lenticular, poorly to well sorted, poorly to well cemented, moderately permeable.

The San Onofre Breccia is characterized by abrupt lateral and vertical changes from sandy to earthy matrices and widely varying dominant and maximum sizes of clasts ranging from small pebbles to huge blocks as large as 12 feet in maximum dimension. The clasts include quartzite, quartz schist, quartz albite schist, blue and green schists rich in amphiboles and saussuritized gabbro ranging in size from fine to coarse, angular to rounded sand, pebbles and cobbles to angular to subrounded boulders up to five feet in the smallest dimension.

The San Onofre Breccia appears locally to interfinger with parts of the predominantly younger Monterey Formation and is conformable with the underlying Topanga Formation within the Dana Point quadrangle. A few identifiable fossils suggestive of the middle Miocene have been found in the San Onofre Breccia (Woodford, 1925, p. 205-209; Vedder, in Bergen, 1971, p. 16-17). The maximum section of San Onofre Breccia measured by Woodford is 2,610 feet in the sea cliff southeast of Laguna Beach a few miles northwest of the Dana Point quadrangle (Woodford, 1925, p. 185). Exposures within the Dana Point quadrangle indicate the section locally is at least 1,000 feet thick

Rocks of the San Onofre Breccia are deformed mainly by faulting and by many shears of little apparent displacement. Both phenomena are widespread, but are generally notable only in cut faces and in the sea cliff. The minor faults and shears are generally not traceable into the overlying terrace deposits or into adjacent younger formations suggesting that most are penecontemporaneous structures. One possible exception occurs at the western end of Dana Point where marine terrace (Qtm_1) may have been displaced about four feet vertically. The exposure there is poor, however, and the apparent displacement may be due to draping of the terrace over a differentially eroded surface.

The San Onofre Breccia is generally stable because it is mostly well cemented and composed of conglomerate and sandstone which resist erosion and sliding. Rocks in shear zones are susceptible to more rapid erosion. This is especially notable along the base of the sea cliff where small sea caves and arches have been formed along shears by wave action. The chaotic and massive structure of much of the San Onofre Breccia provides additional stability to the formation.

Only a few small landslides were noted within the San Onofre Breccia in the Dana Point quadrangle. A large landslide is in the sea cliff about two miles northwest of Dana Point. A block, about an acre in size and partly bounded by a fault, slid on daylighted bedding planes and broke into smaller blocks. The landslide was reactivated during the 1969 rainstorms and several nearby houses close to the sea cliff were endangered.

Grading in the San Onofre Breccia varies greatly from relatively easy to difficult, with occasional blasting required, depending upon the degree of weathering and cementing and the size of clasts. Some cemented zones in the sandstone facies require heavy ripping and blasting. Special disposal is required for the resulting large blocks and for boulders, which are generally very hard and dense. San Onofre Breccia and its soils generally make good fill materials. Fill containing large cobbles and boulders is difficult to compact uniformly and, when derived from the earthy matrix facies, is moderately expansive.

Soils are generally thin, approaching three feet thick on the lower gradient slopes, mostly reddish brown to yellowish brown, sandy and gravelly clay to clayey sand and are slightly to moderately expansive. Slopewash developed from the San Onofre Breccia is mostly reddish brown to moderate brown sandy and gravelly clay as much as six feet thick. It accumulates mostly along the gradient change between relatively flat marine terraces and the moderately steep San Onofre Breccia terrain. It is generally moderately expansive, poorly compacted and moderately permeable.

TOPANGA FORMATION; Map designation; Tt; marine.

Material;

Sandstone and conglomeratic sandstone: light gray to dusky yellow, medium to coarse grained, angular to subrounded grains, subrounded to rounded pebbles, massive to thick bedded, poorly sorted, moderately well cemented, calcareous, moderately permeable.

The Topanga Formation in the Dana Point quadranlge is composed mostly of quartz and feldspar grains with pebbles of acid volcanic and plutonic rocks. Other pebble clasts and many sand grains consist of blue and green schists, quartz schists and saussuritized gabbro similar to those found in the San Onofre Breccia.

The Topanga Formation is only exposed in the Dana Point quadrangle as a lenticular body faulted upward into the San Onofre Breccia section in the northwestern part of the quadrangle. It is the oldest bedrock exposed within the Dana Point quadrangle and grades upward into the San Onofre Breccia in exposures in the sea cliff about two miles to the northwest in the Laguna Beach quadrangle. The Topanga Formation contains middle Miocene mollusks and microfauna of the Relizian Stage in adjacent quadrangles (Woodford, 1925, p. 180 and Smith, 1960, p. 466).

The Topanga Formation is reported to be about 7,000 feet thick in the San Joaquin Hills (Yerkes, et al., 1965, plate 1). Maximum thickness in the Dana Point quadrangle is unknown as its base is not exposed, but the section exposed in the northwestern portion on the south flank of Niguel Hill is at least 140 feet thick. Topanga Formation terrane has moderately steep slopes (up to about 40 degrees) with narrow ridge tops. The Topanga Formation supports sparse to moderate brush growth.

The Topanga Formation is generally stable within the Dana Point quadrangle because here it is mostly moderately well cemented and thick-bedded. Remnants of weathered rock formed by differential erosion are blocky to slabby in shape and generally subrounded. The sandstone is very stable, even on relatively steep slopes that have unfavorable bedding orientation. However, loose slabs on slopes can move downslope in earthflows or mudflows during and after heavy rains.

The Topanga Formation sandstone in the Dana Point quadrangle may require heavy ripping and blasting. Large hard blocks of rock resulting from such grading techniques would require special disposal. Fill composed of less cemented zones of the Topanga Formation is good in quality and stability, except for rilling tendencies. The soil is thin to non-existent, moderate yellowish brown, non-expansive, clayey sand. Slopewash is essentially non-existent.

DESCRIPTION OF SURFICIAL UNITS

ARTIFICIAL FILL; Map designation; AF.
Material; variable in physical properties, color and stability depending upon the source and construction methods.

Artificial fill has been used for highway embankments, highway road base, flood control embankments, valley fills and slope fills. Most fill material is locally obtained and commonly exhibits engineering properties similar to its parent material. Artificial fill has been mapped only where it is significantly large enough to be shown at a scale of 1:12,000.

STREAM ALLUVIUM; Map designation; Qal.
Material: sand, silt, clay and some gravel; generally moderate yellowish brown to grayish brown, poorly to locally well sorted, permeable, unconsolidated.

The sand is composed mostly of angular to subrounded, fine- to coarse-grained quartz and feldspar with abundant grains of metavolcanic rocks and quartzite. The gravel is composed mostly of granodiorite, quartz diorite, and quartzite. Minor amounts of andesite, unidentified volcanic and metavolcanic rocks, and blue and green schists are also present. The fine-grained alluvium is generally poorly consolidated sandy silt to sandy clay. Alluvium has been mapped only in San Juan Creek and Trabuco Creek. Alluvium in the smaller drainage courses is included with the slopewash. In San Juan Creek the alluvium is up to 200 feet thick (Stout, 1969, p. 174-175, and Meidav, 1969, p. 10-11).

Although many of the stream beds are dry during most of the year, ground water is near the surface in most. Some streams are developing year round surface flow mainly due to irrigation within adjacent urban developments. (See Appendix A for physical properties including rippability, soil classification, expansivity and consolidation potential).

BEACH SEDIMENTS; Map designation; Qb.
Material: sand, silty sand and some gravel; fine to coarse grained, commonly micaceous, light gray, dusky yellow to pale yellowish brown, moderately to well sorted, subangular to rounded, permeable, unconsolidated. Some sandy fill is included in this unit, especially in the area of Doheny Beach State Park and southeastward of San Clemente.

The beach sediments are composed largely of sand sized quartz, feldspars and rock fragments derived from the stream alluvium and formations exposed along the seacoast. The beach sediments interfinger with the stream alluvium and slopewash where the major drainage courses approach the sea.

Littoral currents carry the sediments southward along the coast during the winter and spring, and northward during the summer and fall, with the southern movement predominating in volume of material transported. Winter storms generate waves which erode and narrow the exposed portion of the beach. Sand accumulates in the underwater portion of the beach until waves of lower velocity and longer period return it onto the shore during the summer. However, some sand moves down the coast to other beaches, or seaward to irretrievable depths. Sands are washed onto the beach from the larger drainage courses during runoff from major rainstorms; but generally a deficiency in replenishment of beach sands has occurred historically. Dams, lined flood control channels and prolonged periods of below average rainfall with few major rainstorms limit the movement of sand toward the seacoast (Newton, 1960, p. 18-36).

POND ALLUVIUM; Map designation; Qalp.
Material: silt and clay; dark gray to grayish brown, white and light gray, laminated, poorly consolidated, derived mainly from siltstone of the Capistrano Formation.

These deposits are as much as ten feet thick, of Holocene age, situated upstream from small earthfill dams, and are of limited areal extent.

FAN ALLUVIUM; Map designation; Qalf.
Material: gravel, sand, silt and clay; medium gray, grayish brown to moderate brown, poorly sorted, subangular to rounded, fine to coarse grained, relatively permeable, poorly consolidated.

Fan alluvium has been mapped primarily at the mouths of tributaries of Salt Creek and San Juan Creek. It also occurs on landslides on the south side of San Juan Creek where it was differentiated on the basis of geomorphic appearance and the abundance of coarse materials. These deposits are ten to 15 feet thick, and of limited areal extent. They interfinger with stream alluvium and slopewash.

SLOPEWASH; Map designation; Qsw.
Material: the slopewash deposits are derived principally from upslope bedrock sources. Where the slopewash is derived from siltstone of the Capistrano Formation, it is medium-gray to grayish-brown, poorly sorted, poorly consolidated, fine, sandy silt and silty clay; where derived from San Onofre Breccia, it is moderate-yellowish-brown to moderate-brown, poorly consolidated sandy clay with gravel; where derived from shale and siltstone of the Monterey Formation, it is black and dark-gray to dark-yellowish-brown, poorly consolidated silty clay with limy shale gravel (see Description of Bedrock Units). All of these slopewash deposits are moderately to highly permeable.

Slopewash has been mapped where it is estimated to exceed three feet in thickness. The deposits commonly are as much as ten feet thick, but locally they attain a thickness of 40 feet on the large slide masses along the southeast side of San Juan Creek. Slopewash deposits occur primarily near the heads of gullies and bases of slopes. As mapped, these deposits include some stream alluvium. In such areas, the mapped unit contains scattered gravel and sand and gravel lenses derived from the lower parts of nearby marine terrace deposits and the Niguel Formation.

TALUS; Map designation; Qtal.
Material: heterogeneous mixture of rock slabs, boulders, cobbles and pebbles, with sandy to silty matrix; mostly medium gray and moderate yellowish brown to moderate brown; generally loose and unconsolidated, moderately to highly permeable.

Talus deposits are located at the base of sea cliffs. Talus creeps and slides down-slope due to the force of gravity. Heavy rains cause severe gullying and massive failure of talus deposits. Undercutting by wave action, stream erosion or grading by man also causes massive failures. Talus that is not exposed to wave action at the base of old sea cliffs (e.g., along State Highway 1 between Capistrano Beach and San Clemente) protects slopes from active erosion and tends to delay block fall from the cliffs.

LANDSLIDES; Map designation; Qls.
Material: variable in physical properties, color and stability depending upon geologic unit involved in the landsliding, type of slope failure, and distance and age of movement.

Landslides are numerous and widespread, including block-glide, earthflow, and rotational slump type of failures (Varnes, 1958, p. 20-47). Planar features such as joints and faults are common failure surfaces in many landslides within the quadrangle.

Most landslides are caused by oversteepening of slopes by stream erosion, infiltration of surface waters through shrinkage cracks in expansive soils and through more permeable overlying materials, and the weakening of bedrock by deep weathering, jointing and shearing. Landslide morphology is typically hummocky having an adjacent arcuate scarp or abruptly steeper slope. The toe of the landslide commonly crowds, diverts or blocks a canyon or gully. Subsurface drainage channels are commonly present. Large landslides commonly exhibit more youthful topography than adjacent areas and may contain undrained depressions. Some landslides have very subdued topographic outlines and are difficult to detect. Landslide deposits are generally unstable and poorly consolidated to loose.

Renewed movement of old landslides may be initiated by the addition of water or by the removal of either lateral or toe support. Scarp areas are generally oversteepened and prone to landsliding. Severe gullying of the slide mass commonly occurs during heavy rainfalls. Some landslides include large coherent and, in some formations, hard blocks which may be mistaken for undisturbed bedrock during an exploration and testing program.

STREAM TERRACE DEPOSITS; Map designation; Qt.
Material; sandy clay, gravelly clay, some sandy silt, gravel, and silty sand; moderate yellowish brown to moderate brown and moderate reddish brown to grayish brown, poorly to moderately well bedded, poorly to well sorted, slightly to moderately permeable, poorly to moderately well consolidated.

The sand is mostly quartz and feldspars. The gravel includes sub-angular to rounded pebbles, cobbles and small boulders mostly of granodiorite, quartz diorite and quartzite with minor amounts andesite, other volcanic and metavolcanic clasts and metamorphic schistose debris derived from the San Onofre Breccia.

The stream terrace deposits in the Dana Point quadrangle are as much as 60 feet thick, the greatest thickness being along the northwest side of San Juan Creek (Meidav, 1969, p. 11-12). Within the stream terrace deposits are lenses and beds of silt, sand and gravel up to ten feet thick. Basal contact with underlying rocks is generally planar with local channeling and slopes gently toward the existing stream courses and the sea. Near the mouth of San Juan Creek the stream terrace interfingers with and is difficult to distinguish from the nonmarine terrace deposits (Qtn - see below). Stream terrace terrain slopes gently to moderately toward the existing stream courses and is cut by moderately steepsided tributary channels. Irrigation of citrus and avocado groves along San Juan Creek and occasional heavy winter rains locally and periodically saturate these stream terrace deposits. Seepage which often results in small surficial slope failures commonly occurs along the base of the terrace deposits. The stream terrace deposits are otherwise relatively stable unless underlain by weak formations adjacent to steep-sided gullies or canyons.

NONMARINE TERRACE DEPOSITS; Map designation; Qtn.
Material: silt and clay; brownish gray and grayish brown to moderate yellowish brown, poorly bedded, poorly sorted, slightly permeable, well to poorly consolidated. Pleistocene to Holocene alluvial cover on marine terrace deposits.

These deposits locally contain chips of hard, pale-yellowish-brown to white shale, are weakly cemented with limy and ferruginous cements and grade into small stream channel deposits of pebbles and cobbles of milky quartz and varicolored volcanic and metamorphic rocks.

These nonmarine deposits are made up of materials which have been accumulating on marine terrace deposits since the uplift of the terrace level above sea level. They unconformably overlie marine terrace deposits and are locally interfingered with the stream terrace deposits.

They are commonly as much as 20 feet thick and support low steep slopes with only minor sloughing. Terrain developed on these deposits is relatively flat to gently rolling, mostly sloping gently toward the sea or toward steepsided drainage courses. These terrace deposits are numbered with subscripts indicating relative levels, one being the lowest in elevation (after the system used by Vedder, et al., 1957).

MARINE TERRACE DEPOSITS; Map designation; Qtm.
Material; fine to coarse sand, commonly with basal gravel; moderate yellowish brown to moderate brown, faintly bedded, cross bedded, moderately well sorted, porous, highly permeable, poorly consolidated to loose.

The sand grains and gravel clasts are subrounded to rounded. These deposits are locally weakly cemented with limy and ferruginous cements. They contain a few molluscan fossils and pholad-bored cobbles. The marine terrace deposits mapped are up to 50 feet thick and unconformably overlie the Capistrano Formation, the Monterey Formation and the San Onofre Breccia. These deposits occur mostly at levels one, two and three of the series of terrace deposits designated by subscripts on the accompanying geologic map, with one being the lowest in elevation. Marine terrace deposits up to 20 feet thick unconformably underlie the nonmarine terrace deposits at most levels. The basal contacts with the bedrock formations are generally planar and slope very gently south and southwest toward the existing seacoast.

The marine terrace terrain is flat to very gently rolling and commonly has scattered small sand mounds. The surfaces slope gently toward the sea or toward the relatively steepsided courses. These deposits may be seasonally saturated, especially near the base where seepage from irrigation and heavy winter rains collects and moves downslope toward the sea.

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Appendix A

Summary of Characteristics of Surficial Units*

Map Designation	Soil Classification[1]	Rippability[2]	Expansivity	Consolidation Potential	Erosion	Permeability	Vegetation	Use Potential
Qal	CL, ML, SC, SM, SP, GC, GP	4	Sand & gravel-low to none silt & clay-moderate to high	Moderate	Moderate to severe rilling	Sand & gravel-moderate to high silt & clay-low to moderate	Phreatophytic trees and shrubs, row crops	Agriculture, sand and gravel, urban development (if protected from flooding)
Qb	SP, SM, GP	4	None	Low to moderate	Severe wave erosion, low to moderate wind erosion	High	None	Recreation
Qalp	CL, ML	4	Moderate to high	Moderate to high	Local rilling & piping	Low	Phreatophytic shrubs & reeds	Artificial pond lining and earthfill dam cores
Qalf	CL, ML, SM, SP, GP	4	None to moderate	Moderate	Moderate rilling	Moderate to high	Grass & shrubs	Artificial fill
Qsw	CL, ML, (locally GC, GP, SM, SC, SP)	4	Moderate	Moderate	Moderate rilling & earth-flows	Low to moderate	Grass & shrubs	Artificial fill
Qtal	Variable depending upon source	3-4	Low to moderate	Moderate to high	Moderate to severe rilling, piping and sliding	Moderate to high	Shrubs or none	Artificial fill

(Appendix A continued on page following)

Appendix A (continued)

Summary of Characteristics of Surficial Units*

Map Designation	Soil Classification[1]	Rippability[2]	Expansivity	Consolidation Potential	Erosion	Permeability	Vegetation	Use Potential
Qls	Variable depending upon source	4 (locally 2)	Low to moderate	Moderate to high	Moderate to severe rilling and piping, earthflows and renewed sliding	Low to high	Grass, shrubs, phreatophytes	Artificial fill, some large landslide areas would make good parks and greenbelt areas and be suitable for horse trails or recreation vehicle areas; some large landslides are currently used for agriculture
Qt	GC, GP, SM, SP, ML, CL	3-4	None to moderate	Low to moderate	Moderate rilling and earthflows	Low to high	Grass, shrubs, fruit trees	Artificial fill, agriculture, urban development
Qtn	ML, CL, GC, SC	3-4	Low to moderate	Low to moderate	Moderate rilling, piping, and earthflows	Low to moderate	Grass, shrubs	Artificial fill, agriculture, urban development
Qtm	SP, SM, GP	4	None	Low to moderate	Moderate to severe rilling, piping, sand flows, wind erosion	High	Sparse grass & shrubs	Permeable fill, limited sand and gravel, potting soil, urban development

*Classification of units and their characteristics is based upon the author's experience and judgment in relation to field observations and field and laboratory tests by various government agencies and private consultants

[1] See Appendix C

[2] See Appendix D

Appendix B

Summary of Engineering Characteristics of Bedrock Units*

Map Designation	Soil Classification[1]		Rippability[2]	Expansivity		Consolidation Potential	Erosion	Permeability	Vegetation	Use Potential
	Soil	Disaggregated Bedrock		Soil	Disaggregated Bedrock					
Tn	ML, CL	CL, ML (some GC and SM)	4 (locally 3)	Low to moderate	Low to moderate	Low to moderate	Moderate rilling and piping	Moderate to low	Brush, grass, cactus	Grazing, urban development
Tc	ML, CL	ML, CL (some SP)	4	Low to high	Low to moderate	Low to moderate	Moderate rilling, piping, and earth-flows	Low (local moderate)	Brush, grass, cactus (mustard)	Grazing, urban development, expanded aggregate raw material
Tc_{dsts}	ML, CL	ML, CL	4	Low to moderate	Low to moderate	Low to moderate	Moderate rilling and piping	Low to moderate	Brush, grass	Urban development
Tc_{ss}	SM, ML, CL	SM, SP	4-2	Low to moderate	None to low	Low to none	Low to moderate rilling	Moderate	Brush, grass, cactus	Grazing, urban development, permeable fill
Tc_{ss+bc}	SM, ML, CL	SM, SP (some GM).	4-1	Low to moderate	None to low	Low to none	Local rilling	Moderate	Brush, grass, cactus	Grazing, urban development permeable fill, riprap
Tm	CL, CL-CH	CL, ML (some SM)	4 (locally 2)	Moderate to high	Low to moderate	Low to moderate	Low to moderate rilling, piping, and earth-flow	Low (local moderate)	Grass, cactus (mustard)	Grazing, urban development

(Appendix B continued on page following)

Appendix B (continued)

Summary of Engineering Characteristics of Bedrock Units*

Map Designation	Soil Classification[1]		Rippability[2]	Expansivity		Consolidation Potential	Erosion	Permeability	Vegetation	Use Potential
	Soil	Disaggregated Bedrock		Soil	Disaggregated Bedrock					
Tso	GC, CL	GC, GM, SC, CL	3-1	Low to high	Low to moderate	Low to none	Local rilling and earthflow	Low to moderate	Brush, chaparral, cactus	Urban development, decorative rocks for landscaping, mineral specimens, riprap
Tso$_{SS}$	SM, ML, CL	SP, SM, SC	3-1	Low to moderate	None to low	Low to none	Local rilling	Moderate	Brush, chaparral, cactus	Urban development, permeable fill, riprap
Tt	SM, ML, CL	SP, SM	3-1	Low	None to low	Low to none	Local rilling	Moderate	Brush, cactus	Urban development, permeable fill

*Classification of units and their characteristics is based upon the author's experience and judgment in relation to field observations and field and laboratory tests by various government agencies and private consultants.

[1] See Appendix C

[2] See Appendix D

Appendix C

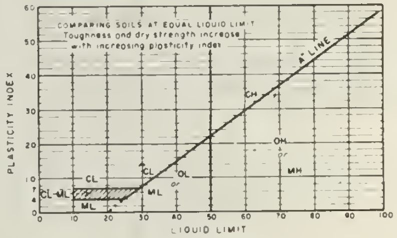
Soil Classification

The classification used is based upon the field classification methods detailed in the Unified Soil Classification System as described in the Earth Manual, Bureau of Reclamation (Hilf, 1968). The chart reproduced on the following page is taken from the Earth Manual as modified by the California Department of Water Resources.

The classification used for sedimentary rocks is indicative of the engineering characteristics of a sample disaggregated by standard grading procedures for use as fill material. In situ bedrock may have engineering characteristics different from those of its disaggregated state.

UNIFIED SOIL CLASSIFICATION CHART *(INCLUDING IDENTIFICATION AND DESCRIPTION)*

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 3 inches and basing fractions on estimated weights)							GROUP SYMBOLS[1]	TYPICAL NAMES	INFORMATION REQUIRED FOR DESCRIBING SOILS	LABORATORY CLASSIFICATION CRITERIA
COARSE GRAINED SOILS More than half of material is larger than No 200 sieve size[2] (The No 200 sieve size is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than No 4 sieve size (For visual classifications, the ¼" size may be used as equivalent to the No 4 sieve size)	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes				GW	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name, indicate approximate percentages of sand and gravel, max size, angularity, surface condition, and hardness of the coarse grains, local or geologic name and other pertinent descriptive information, and symbol in parentheses For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics **EXAMPLE -** Silty sand, gravelly, about 20% hard, angular gravel particles ½-in maximum size, rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength, well compacted and moist in place, alluvial sand, (SM)	Use grain size curve in identifying the fractions as given under field identification Determine percentages of gravel and sand from grain size curve Depending on percentage of fines (fraction smaller than No 200 sieve size) coarse grained soils are classified as follows Less than 5% GW, GP, SW, SP, More than 12% GM, GC, SM, SC, 5% to 12% Borderline cases requiring use of dual symbols $C_u \; \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{50})^2}{D_{10} \times D_{60}}$ Between one and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing				GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW
		GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)				GM	Silty gravels, poorly graded gravel-sand-silt mixtures		Atterberg limits below "A" line, or PI less than 4 Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols
			Plastic fines (for identification procedures see CL below)				GC	Clayey gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits above "A" line with PI greater than 7
	SANDS More than half of coarse fraction is smaller than No 4 sieve size	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes				SW	Well graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing				SP	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW
		SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)				SM	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line or PI less than 4 Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols
			Plastic fines (for identification procedures see CL below)				SC	Clayey sands, poorly graded sand-clay mixtures		Atterberg limits above "A" line with PI greater than 7
FINE GRAINED SOILS More than half of material is smaller than No 200 sieve size			IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN No. 40 SIEVE SIZE	DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATANCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)				
	SILTS AND CLAYS Liquid limit less than 50			None to slight	Quick to slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions **EXAMPLE -** Clayey silt, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML)	Use grain size curve in identifying the fractions as given under field identification
				Medium to high	None to very slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
				Slight to medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity		
	SILTS AND CLAYS Liquid limit greater than 50			Slight to medium	Slow to none	Slight to medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts		
				High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays		
				Medium to high	None to very slow	Slight to medium	OH	Organic clays of medium to high plasticity		
HIGHLY ORGANIC SOILS			Readily identified by color, odor, spongy feel and frequently by fibrous texture				Pt	Peat and other highly organic soils		



PLASTICITY CHART

FOR LABORATORY CLASSIFICATION OF FINE GRAINED SOILS

[1] Boundary classifications - Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well graded gravel-sand mixture with clay binder

[2] All sieve sizes on this chart are U.S. standard

FIELD IDENTIFICATION PROCEDURES FOR FINE GRAINED SOILS OR FRACTIONS

These procedures are to be performed on the minus No 40 sieve size particles, approximately $\frac{1}{64}$ in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests

DILATANCY (Reaction to shaking)

After removing particles larger than No 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction

DRY STRENGTH (Crushing characteristics)

After removing particles larger than No 40 sieve size, mold a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun, or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour

TOUGHNESS (Consistency near plastic limit)

After removing particles larger than the No 40 sieve size, a specimen of soil about one-half inch cube in size is molded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch in diameter. The thread is then folded and rerolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line

Highly organic clays have a very weak and spongy feel at the plastic limit

103-D-347

Appendix D

Scale of Rippability

1. Very hard to hard. Blasting necessary to probably necessary.

2. Hard to moderately hard. Blasting probably necessary to rippable with difficulty.

3. Moderately hard to firm. Rippable with difficulty to easily ripped.

4. Firm to soft. Easily ripped to easily cut.

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DEPARTMENT OF BUILDING AND SAFETY, ROAD DEPARTMENT
AND THE ORANGE COUNTY FLOOD CONTROL DISTRICT

DANA POINT QUADRANGLE
SPECIAL REPORT 109 PLATE I

DANA POINT QUADRANGLE

EXPLANATION

SURFICIAL UNITS

QUATERNARY — HOLOCENE — PLEISTOCENE

AF	Artificial fill
Qal	Stream alluvium
Qb	Beach sediments
Qalp	Pond alluvium
Qalf	Fan alluvium
Qsw	Slopewash deposits
Qtal	Talus
Qls	Landslide deposits
Qt	Stream terrace deposits
Qtn_{1-5}	Nonmarine terrace deposits
Qtm_{1-4}	Marine terrace deposits

BEDROCK UNITS

TERTIARY — PLIOCENE — MIOCENE

Tn	Niguel Formation; marine sandstone, sandy siltstone and conglomerate
Tc	Capistrano Formation; marine siltstone, mudstone and silty shale
Tc_{sts}	
Tc_{dsts}	diatomaceous siltstone and shale
Tc_{ss}	sandstone and conglomeratic sandstone
Tc_{ss+bc}	sandstone with conglomerate and sedimentary breccia lenses
Tm	Monterey Formation; marine diatomaceous shale, silty shale, siliceous shale, chert and calcareous shale
Tso	San Onofre Breccia; marine earthy to sandy sedimentary breccia, conglomerate and conglomeratic sandstone,
Tso_{ss}	sandstone
Tt	Topanga Formation; marine sandstone and conglomeratic sandstone

SYMBOLS

Contact
Dashed where approximately located; queried where inferred; dotted where concealed.

Creep area
Gravity creep of soil and/or bedrock downslope.

Fault
Dashed where approximately located;

Erosional gully

Tso_ss	breccia, conglomerate and conglomeratic sandstone, sandstone
Tt	Topanga Formation; marine sandstone and conglomeratic sandstone

SYMBOLS

Contact
Dashed where approximately located; queried where inferred; dotted where concealed.

Fault
Dashed where approximately located; queried where inferred; dotted where concealed. U, up thrown side; D, down thrown side. Arrow shows direction and number shows amount of dip on fault plane.

24 Strike and dip of beds.

15 Approximate strike and dip of beds.

⊕ Horizontal beds.

12 Approximate direction of dip of beds.

82 Strike and dip of shear surface.

Vertical shear surface.

85 Strike and dip of joint plane.

Vertical joint plane.

Qsw/Qls Qalf/Qls Surficial unit overlying landslide deposit.

Landslide
Arrows indicate direction of failure; showing scarp where apparent; queried where uncertain; i, incipient failure; superimposed where additional and more recent failure has occurred on older landslide; landslide deposits are generally more than 10 feet thick.

Creep area
Gravity creep of soil and/or bedrock downslope.

Erosional gully
Steep-sided; two or more feet deep, as much as 40 feet deep on ancient landslides.

Subsurface drainage channel
Formed by piping; holes locally open to ground surface; as much as 10 feet deep.

Bed
Mappable thin bed within formation.

Boulder riprap
Protection against wave erosion along seacoast and stream erosion along creek channel.

Cut face
Graded in bedrock and/or soil; not all cut faces are delineated.

Spring
Mostly intermittent; commonly irrigation seepage.

Core hole or well drilled for oil.

Surface mining area
Approximate boundary of stripping for expanded aggregate raw material in Prima Deshecha Canada area.

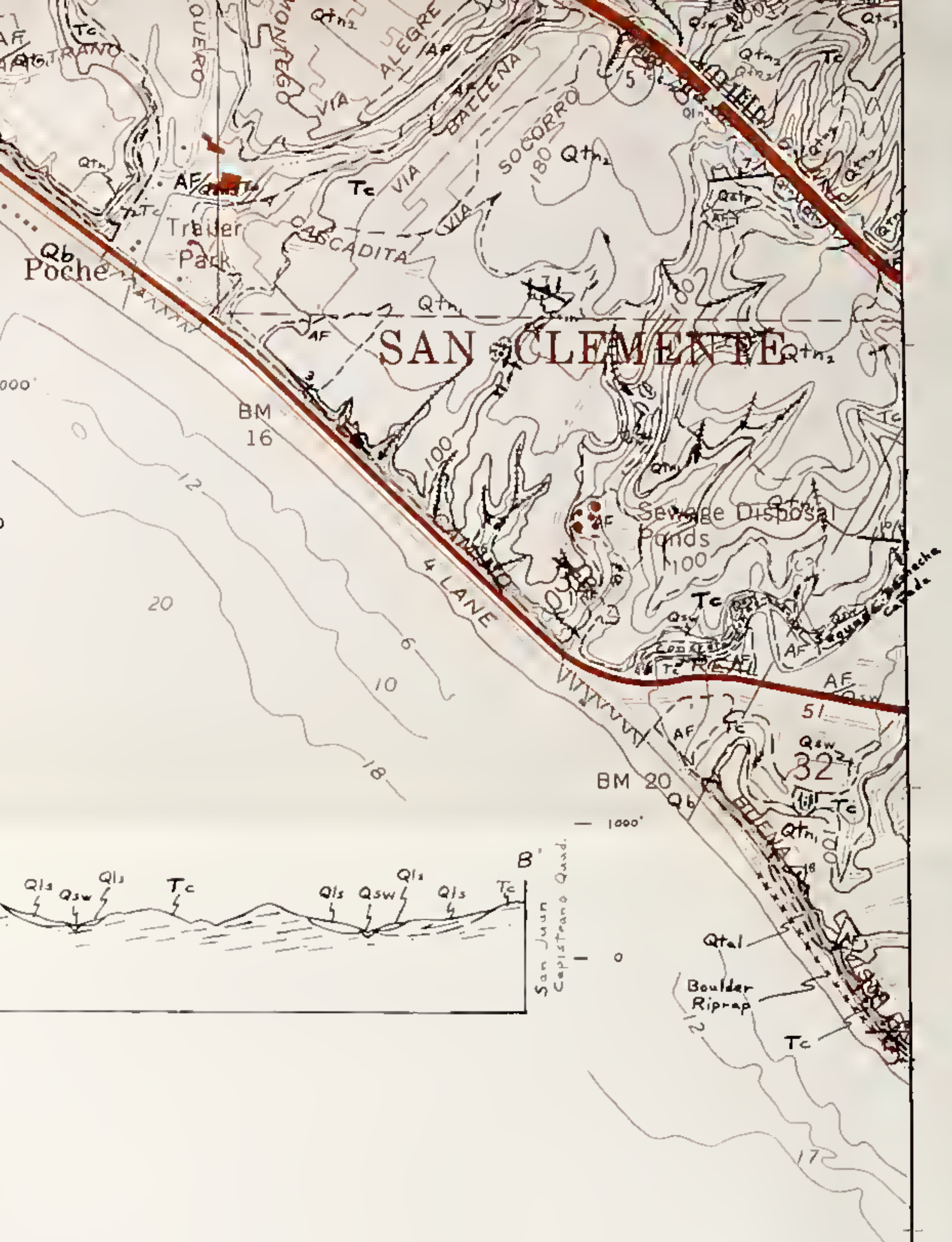
Shallow landslide or earthflow
Arrows indicate direction of failure; showing scarp where apparent; shallow landslide and earthflow deposits are generally less than 10 feet thick.

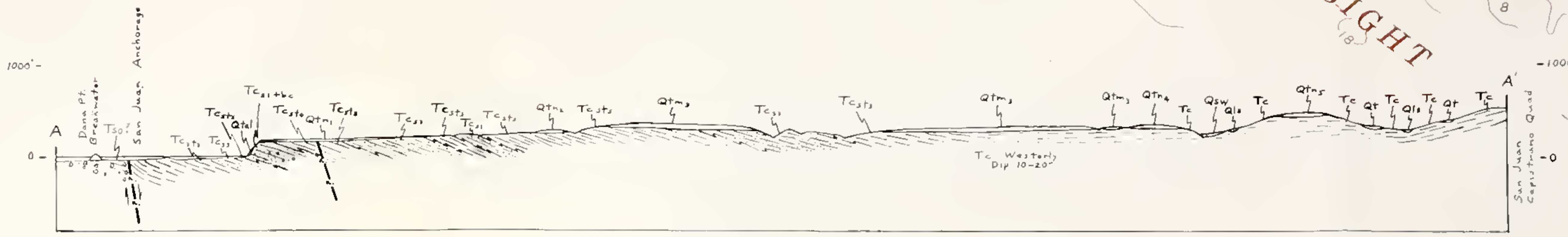
GEOLOGY BY W.J. EDGINGTON, 1968-1969

Core Holes and Wells Drilled For Oil

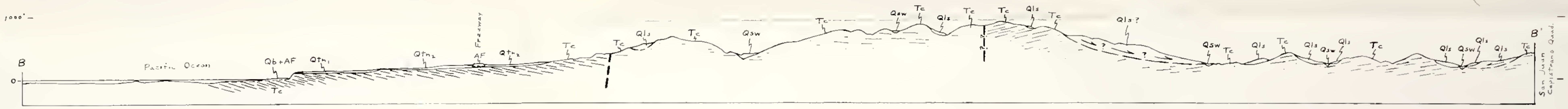
1 T.8S., R.8W., Sec.11 Continental Oil Co., Capron 1
2 T.8S., R.8W., Sec.23 Union Oil Co., Vaciadero Fee Core Hole.
3 T.8S., R.8W., Sec.13 C.A.Welsh, O.K. CARR 2.
4 T.8S., R.8W., Sec.13 Shell Oil Co. Krum C.F. 42.
5 T.8S., R.7W., Sec. 7 Roy Gill, Krum 1.
6 T.8S., R.7W., Sec 8 Mineral Exploration Co., Ltd., 1.

References: OM-193; Vedder, J.G. et al., 1957, U.S. Geological Survey Exploratory Wells Drilled Outside of Oil and Gas Fields in California to Dec.31, 1963; California Division of Oil and Gas.

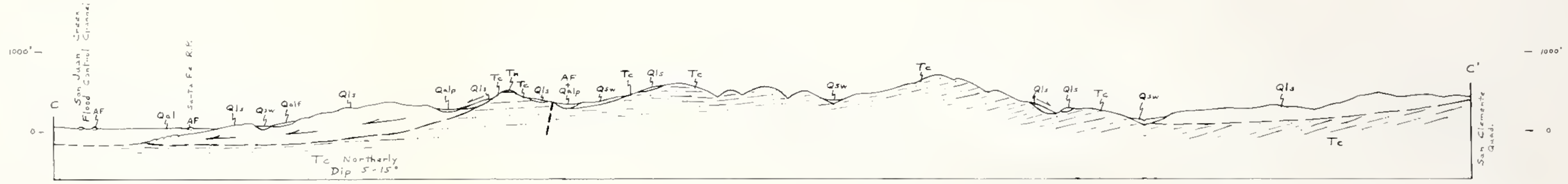




SECTION A-A'



SECTION B-B'



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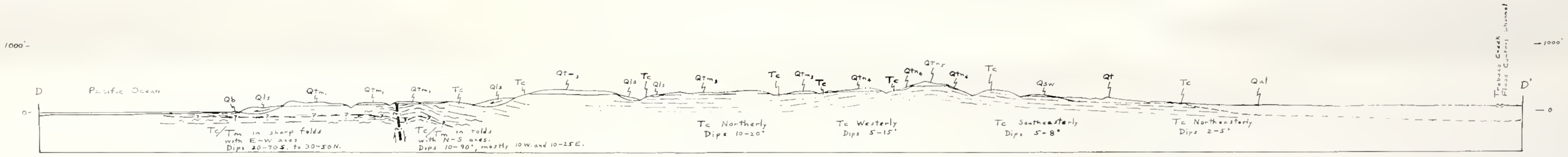

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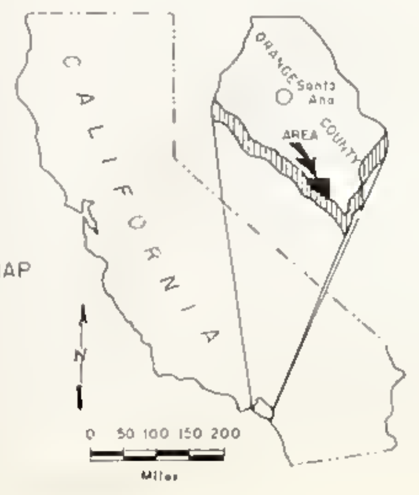
Pacific Ocean
Tc/Tm in sharp folds with E-W axes Dips 20-70 S. to 30-50 N.
Tc/Tm in folds with N-S axes. Dips 10-90°, mostly 10 W. and 10-15 E.
Tc Northerly Dips 10-20°
Tc Westerly Dips 5-15°
Tc Southeasterly Dips 5-8°
Tc Northeasterly Dips 2-5°
Trabuco Creek Flood Control Channel
Qal
Qt
Qsw

SECTION D-D'

INDEX MAP



GEOLOGIC MAP AND SECTIONS OF THE DANA POINT QUADRANGLE, ORANGE COUNTY, CALIFORNIA

BY W.J. Edgington, Geologist

1974

Scale 1:24,000
0 1000 2000 3000 4000 5000 6000 FT.
SCALE IN FEET

CONTOUR INTERVAL IS 20 FEET
DASHED LINES REPRESENT 10 FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

N

TOPOGRAPHIC BASE MAP BY U S GEOLOGICAL SURVEY
This map is an enlargement of a
1:24,000-scale published map

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42°30'
40'
117°37'30"

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